Efficacy of right axillary artery perfusion for antegrade cerebral perfusion in open total arch repair

Arudo Hiraoka, MD, Genta Chikazawa, MD, PhD, Toshinori Totsugawa, MD, PhD, Kentaro Tamura, MD, Taichi Sakaguchi, MD, PhD, Kosuke Nakajima, CE, and **Hidenori Yoshitaka, MD, PhD,** *Okayama, Japan*

Objective: **Right axillary artery (RAxA) perfusion was introduced for selective antegrade cerebral perfusion in total aortic arch repair to prevent cerebral embolism derived from arterial cannulation. However, the strategic benefits and long-term results regarding the cannulation site remain controversial. We retrospectively compared the outcomes between propensity score-matched patients with and without using RAxA cannulation.**

Methods: **Between 2006 and 2012, 260 consecutive patients underwent total arch repair with antegrade cerebral perfusion and moderate hypothermia at a single institution. RAxA cannulation was added in 142 patients (54.6%), and 70 propensity score-matched pairs were obtained.**

Results: **There were no significant differences in 30-day (2.9% [2 of 70] vs 5.7% [4 of 70]; $P = .415$ and in-hospital death (5.7% [4 of 70] vs 5.7% [4 of 70]; $P = 1.000$) between matched pairs. Although there was no significant difference in the occurrence of postoperative stroke (8.6% [6 of 70] vs 8.6% [6 of 70]; $P = 1.000$), the new rate of new occurrence of postoperative paraparesis was lower in patients with RAxA perfusion (0% [0 of 70] vs 4.3% [3 of 70]; $P = .067$). With a mean follow-up period of 1057 ± 686 days, the overall 5-year survival was 90.6% and was 89.6% for patients with RAxA perfusion. Thee difference in survival between patients with and without RAxA perfusion was not significant.**

Conclusions: **RAxA perfusion is a useful option for total aortic arch repair, and the midterm outcomes were satisfactory. However, RAxA perfusion did not completely prevent stroke in patients with an atherothrombotic aorta. (J Vasc Surg 2014;60:436-42.)**

Open aortic arch repair with a combination of hypothermic circulatory arrest (HCA) and selective antegrade cerebral perfusion (SACP) is an established option for various aortic pathologies, and the efficacy has been verified.[1-4] However, cerebral embolism derived from arterial cannulation can occur, and postoperative neurologic adverse events are still critical issues. As a preventive measure, right axillary artery (RAxA) perfusion was introduced for SACP in aortic arch repair, and the efficacy has been reported.[5-7] However, the lack of randomized trials and different inclusion criteria do not advocate a general recommendation for incorporating RAxA perfusion in aortic arch repair.[8] Thus, to date, the real benefit of AxA cannulation techniques in open total arch repair and long-term results regarding the cannulation site remain controversial. To evaluate the precise efficacy of RAxA cannulation, we retrospectively compared the outcomes between patients matched for propensity score with and without RAxA cannulation in open total arch repair with HCA and SACP.

From the Department of Cardiovascular Surgery, The Sakakibara Heart Institute of Okayama.

Author conflict of interest: none.

Reprint requests: Arudo Hiraoka, MD, Department of Cardiovascular Surgery, The Sakakibara Heart Institute of Okayama, 2-5-1 Nakaicho, Kita-ku, Okayama 700-0804, Japan (e-mail: bassbord1028@yahoo.co.jp).

The editors and reviewers of this article have no relevant financial relationships to disclose per the JVS policy that requires reviewers to decline review of any manuscript for which they may have a conflict of interest.
0741-5214/$36.00

http://dx.doi.org/10.1016/j.jvs.2014.02.049

METHODS

This study was approved by the Institutional Review Board. Informed consent requirements for patients who participated were waived for this study.

Patients. Between January 2006 and December 2012, 260 consecutive patients (79 women [30.3%]) underwent open total aortic arch repair with HCA and SACP at a single cardiovascular institute. Average age was 71.3 ± 11.0 years (range, 35-92 years). Aortic pathology, including atherosclerosis of the aorta and aortic dissection, were detected by preoperative contrast-enhanced computed tomography applied in the entire cohort. An emergency operation was performed in 88 patients (33.8%).

Of all patients, RAxA cannulation was added in 142 patients (54.6%). We retrospectively compared the outcomes between the 142 patients with and the 118 without RAxA cannulation and evaluated the efficacy of RAxA perfusion by propensity score-matching to reduce the effect of the different backgrounds of patients and potential confounding.

Surgical procedure. General anesthesia was initiated, and transesophageal echocardiography and transcutaneous cerebral oximetry monitoring were routinely performed. Bilateral arterial catheters were placed to monitor systemic and cerebral perfusion pressure during cardiopulmonary bypass (CPB). The aortic arch was approached through a full median sternotomy. The femoral artery and bicaval cannulations were routinely used to establish CPB. The nondissecting ascending aorta with no atherosclerotic lesions was used for CPB.

RAxA cannulation was primarily added for antegrade cerebral perfusion in patients with aortic dissection or severe atherosclerosis in the ascending aorta or aortic arch. The RAxA was exposed through a 5- to 7-cm skin incision at the right axilla, and a 12F to 14F straight cannula was inserted into the RAxA.[5,6] Left atrial venting was initiated through the right upper pulmonary vein. The three cerebral branches of the brachiocephalic artery (BCA), left common carotid artery (LCCA), and left subclavian artery were exposed and encircled.

After systemic cooling to 25°C (bladder temperature) for circulatory arrest, cardiac arrest was achieved by antegrade and selective deliveries of cardioplegic solution into both coronary orifices, and SACP was established at the rate of 500 mL/min for the BCA and 200 mL/min for LCCA and left subclavian artery using two different roller pumps separating from the systemic circulation by inserting 14F to 18F balloon catheters into the three cerebral branches. When cannulation of the RAxA was used, the BCA was clamped for cerebral perfusion. AxA perfusion was adjusted to maintain perfusion pressure between 40 and 60 mm Hg. To prevent postoperative cerebral edema, mannitol was administrated during SACP.

The distal aortic arch was completely separated off at the borderline between the lesion and normal aorta, and a stepwise technique was generally used for distal anastomosis in 147 patients (57%). Moreover, direct distal anastomosis with a four-branched prosthetic graft was performed if at all possible. Femoral artery perfusion was used to flush out debris after open distal anastomosis. After antegrade perfusion through the branch of the graft was restarted, three cerebral vessels and the proximal aorta were reconstructed.

Statistical analysis. Continuous data are presented as mean ± standard deviation and were analyzed using two-tailed *t*-tests or compared with a Mann-Whitney *U* test for independent data, as appropriate. Categoric variables are given as a count and percentage of patients and were compared using χ^2 or the Fisher exact test. Survival rates were estimated using Kaplan-Meier analysis, and survival curves were compared using the log-rank test. Risk factors for death were assessed with a multivariable Cox proportional hazards model. A *P* value of <.05 was statistically considered significant. All data were analyzed using JMP 9.0 software (SAS Institute Inc, Cary, NC).

In addition, we performed adjustment for significant differences in the baseline characteristics of patients with propensity score-matching using a 1:1 nearest neighbor matching algorithm with a ±0.03 caliper and no replacement, yielding 70 propensity score-matched observations. The propensity score was estimated using a multivariate logistic regression model with the variable of use of AxA cannulation given by other studies, and the 19 baseline characteristics entered as covariates.[9] The model fit and predictive power was measured with the C statistic (0.80). We compared standardized differences for all covariates between before and after matching to assess prematch imbalance and postmatch balance. We also performed paired comparisons of intraoperative and postoperative data by using conditional logistic regression analysis for categorical variables and paired *t*-test for continuous variables.

RESULTS

Patient demographics. In unmatched comparison, a significantly younger mean age (68.5 ± 12.2 vs 74.8 ± 8.0 years; $P < .001$) and higher New York Heart Association (NYHA) class (1.2 ± 1.2 vs 0.9 ± 1.0; $P = .023$) was found in patients with RAxA cannulation. A greater percentage of patients with atherosclerotic disease of the aortic arch (39% [56 of 142] vs 20% [24 of 118]; $P = .001$), emergency operation (48% [68 of 142] vs 17% [20 of 118]; $P < .001$), and aortic dissection (54% [76 of 142] vs 20% [24 of 118]; $P < .001$) were observed in the group with RAxA cannulation. Preoperative patient characteristics in the 70 propensity score-matched pairs did not differ significantly, and the preoperative bias was proved to be well adjusted (Table I).

Intraoperative parameter. Although significantly longer operative and cardiac arrest times in patients with RAxA cannulation were found in unmatched pairs, there were no significant differences in the matched comparison. However, lower body circulatory arrest time was significantly longer in patients without RAxA cannulation (58 ± 18 minutes vs 69 ± 20 minutes; $P = .001$). The greater percentage of patients with ascending aorta cannulation was found in patients without RAxA cannulation (20% [14 of 70] vs 79% [55 of 70]; $P < .001$; Table II).

Postoperative mortality and morbidity. The overall 30-day mortality was 5.0% (13 of 260) and in-hospital mortality was 6.5% (17 of 260). Postoperative new stroke (including transient neurologic disorder) was observed in 17 patients (6.5%). There were no significant differences between matched pairs in 30-day (2.9% [2 of 70] vs 5.7% [4 of 70]; $P = .415$) and in-hospital death (5.7% [4 of 70] vs 5.7% [4 of 70]; $P = 1.000$). Although the difference in the occurrence of postoperative stroke between patients with and without RAxA perfusion was not significant (8.6% [6 of 70] vs 8.6% [6 of 70]; $P = 1.000$), the new occurrence rate of postoperative paraparesis, defined as a partial and transient paralysis affecting the lower limbs, was lower in patients with RAxA perfusion (0% [0 of 70] vs 4.3% [3 of 70]; $P = .067$). In addition, postoperative renal function (estimated creatinine clearance) was significantly lower in patients with RAxA cannulation (42.6 ± 23.0 mL/min vs 52.0 ± 26.9 mL/min; $P = .023$; Table III).

Midterm outcome and risk of death. The mean follow-up period was 1057 ± 686 days (range, 1-2716 days; median, 1008 days). The 5-year survival was 90.6% overall and 89.6% for patients with RAxA perfusion. There was no significant difference in survival between patients with and without RAxA perfusion in both unmatched and matched pairs by Kaplan-Meier analysis (Fig 1). Univariate analysis revealed age, atherosclerotic disease of the

Table I. Unmatched and matched comparison of preoperative characteristics

	Unmatched pair			Matched pair		
Variables[a]	*AxA+ (n = 142)*	*AxA− (n = 118)*	P	*AxA+ (n = 70)*	*AxA− (n = 70)*	P
Age, years	68.5 ± 12.2	74.8 ± 8.0	<.001	73.1 ± 8.4	73.1 ± 9.4	.976
Female sex	41 (29)	38 (32)	.590	23 (33)	21 (30)	.724
Body surface area, m^2	1.66 ± 0.21	1.62 ± 0.19	.166	1.62 ± 0.19	1.63 ± 0.20	.824
Hypertension	116 (82)	98 (83)	.871	53 (76)	54 (77)	.827
Hyperlipidemia	35 (25)	32 (27)	.671	19 (27)	18 (26)	.848
Diabetes mellitus	12 (8)	12 (10)	.671	7 (10)	9 (13)	.617
COPD	7 (5)	8 (7)	.598	3 (4)	4 (6)	.707
PVD	19 (13)	13 (11)	.705	12 (17)	7 (10)	.193
Carotid artery stenosis	10 (7)	6 (5)	.609	6 (9)	3 (4)	.315
Hemodialysis	3 (2)	5 (4)	.474	1 (1)	2 (3)	.573
Estimated CrCl, mL/min	70.2 ± 46.6	61.8 ± 28.9	.092	54.3 ± 25.4	62.1 ± 29.8	.091
Atrial fibrillation	15 (11)	12 (10)	1.000	8 (11)	8 (11)	1.000
Atherosclerotic disease of aortic arch	56 (39)	24 (20)	.001	20 (29)	22 (31)	.670
Preoperative TND	11 (8)	5 (4)	.304	3 (4)	4 (6)	.707
Emergency	68 (48)	20 (17)	<.001	16 (23)	14 (20)	.638
Aortic dissection	76 (54)	24 (20)	<.001	19 (27)	19 (27)	1.000
Ruptured aorta	10 (7)	12 (10)	.381	6 (9)	6 (9)	1.000
LVEF, %	64.4 ± 9.7	65.5 ± 9.8	.378	65.2 ± 9.1	64.9 ± 11.3	.893
NYHA class	1.2 ± 1.2	0.9 ± 1.0	.023	1.0 ± 1.0	1.1 ± 1.1	.620

AxA, Axillary artery; *CrCl,* creatinine clearance; *COPD,* chronic obstructive pulmonary disease; *LVEF,* left ventricular ejection fraction; *NYHA,* New York Heart Association; *PVD,* peripheral vascular disease; *TND,* transient neurologic dysfunction.
[a]Continuous data are shown as mean ± standard deviation and categoric data as number (%).

Table II. Unmatched and matched comparison of operative data

	Unmatched pair			Matched pair		
Variables[a]	*AxA+ (n = 142)*	*AxA− (n = 118)*	P	*AxA+ (n = 70)*	*AxA− (n = 70)*	P
Operative time, minutes	464 ± 114	423 ± 98	.002	446 ± 106	441 ± 107	.748
CPB time, minutes	238 ± 62	225 ± 57	.092	224 ± 53	234 ± 68	.293
Cardiac arrest time, minutes	148 ± 38	137 ± 34	.020	136 ± 30	139 ± 38	.682
Cerebral perfusion time, minutes	135 ± 31	133 ± 30	.649	132 ± 30	134 ± 30	.573
Lower body circulatory arrest time, minutes	62 ± 19	65 ± 20	.215	58 ± 18	69 ± 20	.001
Minimum body temperature, °C	24.0 ± 1.8	24.1 ± 2.0	.562	23.9 ± 1.8	23.9 ± 2.2	.867
Ascending aorta cannulation	17 (12)	95 (81)	<.001	14 (20)	55 (79)	<.001
Stepwise distal anastomosis	89 (63)	58 (49)	.033	43 (61)	38 (54)	.423
Concomitant cardiac surgery	49 (35)	42 (36)	.896	28 (40)	26 (37)	.739

AxA, Axillary artery; *CPB,* cardiopulmonary bypass.
[a]Continuous data are shown as mean ± standard deviation and categoric data as number (%).

ascending aorta and aortic arch, ruptured aorta, preoperative transient neurologic dysfunction, operative CPB, cardiac arrest, cerebral perfusion time, and stepwise distal anastomosis as covariates ($P < .1$). By multivariate Cox proportional-hazards regression, independent predictors of midterm death were atherosclerotic disease of the ascending aorta and aortic arch (hazard ratio, 3.3; 95% confidence interval, 1.3-8.4; $P = .012$) and a ruptured aorta (hazard ratio, 4.0; 95% confidence interval, 1.3-11.6; $P = .019$; Fig 2; Table IV).

Subanalysis of RAxA perfusion for patients with aortic dissection and atherosclerotic disease in the aorta. Aortic dissection was observed in 100 patients, and in-hospital death occurred in 6.0% (6 of 100) and postoperative stroke in 7.0% (7 of 100). RAxA perfusion was used in 76 patients (76%). In-hospital mortality and stroke occurrence was 6.6% (5 of 76) and 6.6% (5 of 76), and there were no significant differences between those with ($P = .547$) and without ($P = .173$) RAxA perfusion. By log-rank test, RAxA perfusion had no relevance to the midterm mortality in patients with aortic dissection (Fig 3, *A*). Atherosclerotic disease in the ascending aorta and arch was observed in 80 patients, and in-hospital mortality and occurrence of postoperative stroke was 13.8% (11 of 80) and 11.3% (9 of 80), respectively. Additionally, in the 80 patients, RAxA perfusion was used in 56 patients (70%). The in-hospital mortality rate was 14.3% (8 of 56), and stroke occurred in 10.7% (6 of 56), and there were no significant differences in the percentage between with and without RAxA perfusion (both $P = 1.000$). The log-rank test showed RAxA perfusion did not influence midterm mortality in patients with atherosclerotic disease in the aorta (Fig 3, *B*).

Table III. Matched comparison of postoperative data

		Matched pair		
Variable[a]	*All (N = 260)*	*AxA+ (n = 70)*	*AxA− (n = 70)*	P
30-day death	13 (5.0)	2 (2.9)	4 (5.7)	.415
Hospital death	17 (6.5)	4 (5.7)	4 (5.7)	1.000
Stroke	17 (6.5)	6 (8.6)	6 (8.6)	1.000
Paraparesis	7 (2.7)	0 (0)	3 (4.3)	.067
Reexploration for bleeding	5 (1.9)	2 (2.9)	0 (0)	.153
Reintubation	14 (5.4)	3 (4.3)	4 (5.7)	.658
Initial ventilation time, hours	36.8 ± 79.5	40.7 ± 93.4	26.1 ± 43.6	.305
Mediastinitis	2 (0.8)	0 (0)	0 (0)	…
ICU stay, days	5.5 ± 8.7	6.2 ± 9.7	4.4 ± 5.3	.182
Hospital stay, days	28.4 ± 20.3	31.1 ± 16.6	27.4 ± 17.7	.200

AxA, Axillary artery; *ICU,* intensive care unit.
[a]Continuous data are shown as mean ± standard deviation and categoric data as number (%).

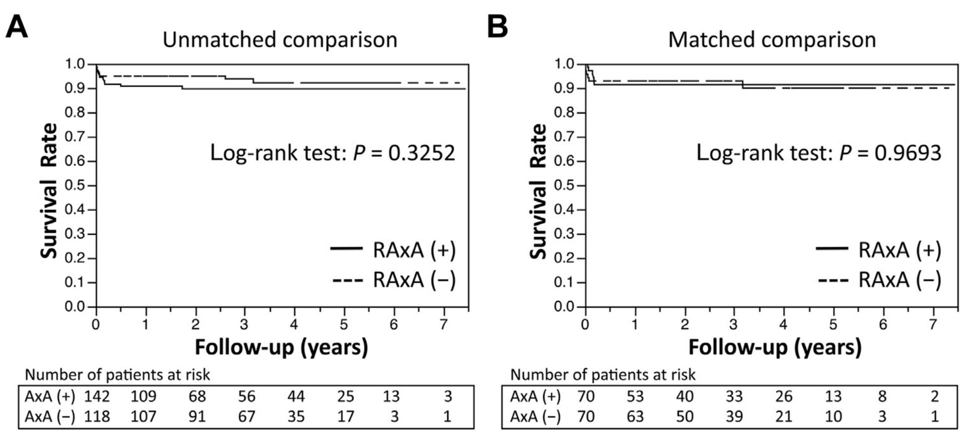

Fig 1. Kaplan-Meier survival on the basis of right axillary artery (*RAxA*) perfusion. **A,** Unmatched comparison between patients with and without RAxA perfusion. **B,** Matched comparison between patients with and without RAxA perfusion.

Axillary artery perfusion with graft or direct cannulation. In the present study, there were 29 patients (20%) with RAxA perfusion through a side graft and 113 (80%) with direct RAxA cannulation. Operative time (487 ± 90 minutes vs 458 ± 119 minutes; $P = .045$) and initial ventilation time (78 ± 174 hours vs 35 ± 49 hours; $P = .026$) were significantly longer in patients with RAxA perfusion through the graft. However, there were no significant differences in the percentage of hospital death and stroke (Table V). The 5-year survival rate was 89.4% in patients with RAxA perfusion by graft and 89.7% in patients with direct RAxA cannulation. However, there were five conversions to single femoral artery cannulation in patients with direct RAxA cannulation, and the causes of conversion included three injured RAxA, one dissected RAxA due to guidewire manipulation, and one high pressure of RAxA perfusion.

DISCUSSION

The AxA is usually free of atherosclerosis and can safely be cannulated directly or with a graft in case severe atherosclerotic change or dissection is found in the ascending aorta or arch. RAxA perfusion can avoid aortic manipulation and retrograde flow of femoral artery cannulation.[10] As a result, RAxA cannulation is proved to be a useful option for prevention of cerebral embolism during CPB,[11] and thus RAxA perfusion has been used for various cardiac and aortic surgeries.[12,13] Several groups have reported better outcomes of RAxA perfusion in aortic dissection repair[14-16] and proximal aortic operation compared with only femoral artery perfusion.[17] In addition, the effect of RAxA perfusion in aortic arch repair has been reported.[5-7] However, there are various preoperative selection biases and differences in technique (directly or with a graft), and evaluating the real benefit of RAxA perfusion is difficult.[8] We adjusted the selection bias by using a propensity score, and evaluated the efficacy of RAxA perfusion. To the best of our knowledge, the present study is the first report on a matched comparison of outcomes between patients with and without RAxA perfusion in total aortic arch repair with SACP.

In the present study, RAxA perfusion was specifically used for patients with atherosclerosis or dissection in the

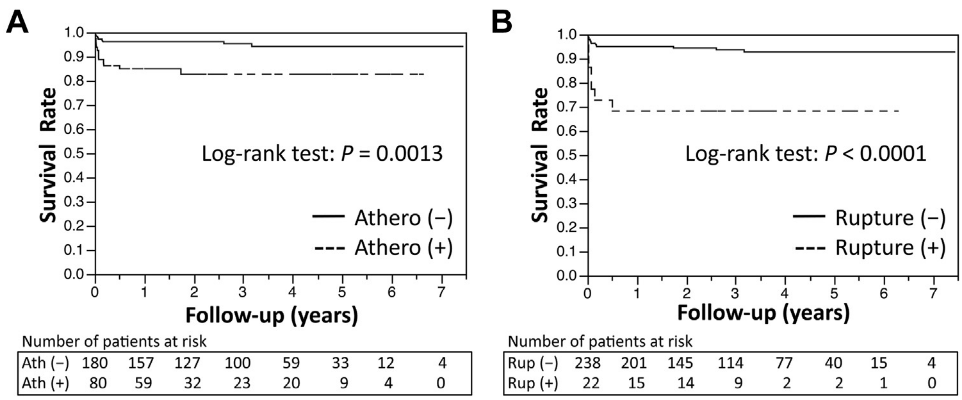

Fig 2. Kaplan-Meier survival on the basis of preoperative risk factors. **A,** Comparison between patients with and without atherosclerotic (*Athero*) disease of the ascending aorta and aortic arch. **B,** Comparison between patients with and without a ruptured aorta.

Table IV. Univariate and multivariate analysis for predictors of midterm mortality

	Univariate analysis		*Multivariate analysis*	
Variables	*HR (95% CI)*	P	*Adjusted HR (95% CI)*	P
RAxA perfusion, +	1.5 (0.66-3.87)	.321		
Age, per year	1.0 (1.00-1.09)	.081		
Atherosclerotic disease of ascending aorta and aortic arch, +	3.7 (1.6-9.0)	.003	3.3 (1.3-8.4)	.012
Ruptured aorta, +	5.7 (2.2-13.6)	.001	4.0 (1.3-11.6)	.019
Preoperative TND, +	5.8 (1.9-14.7)	.004		
Operative time, per minute	1.00 (1.00-1.01)	.040		
CPB time, per minute	1.01 (1.00-1.01)	.012		
Cardiac arrest time, per minute	1.02 (1.00-1.03)	.007		
Cerebral perfusion time, per minute	1.01 (1.00-1.01)	.052		
Stepwise distal anastomosis, +	2.7 (1.1-8.1)	.037		

CI, Confidence interval; *HR,* hazard ratio; *RAxA,* right axillary artery; *TND,* transient neurologic dysfunction.

aorta, younger age, emergency operation, and high NYHA class. Younger age, emergency operation, and high NYHA class were thought to be associated with aortic dissection. Although there were no significant preoperative differences in the propensity score-matched comparison, lower body circulatory arrest time was significantly shorter in patients with RAxA perfusion. Balloon insertion into the BCA for SACP was not required and may be the primary reason for the reduction of circulatory arrest time. A greater percentage of ascending aorta cannulation was due to lesions in the ascending aorta in patients with RAxA perfusion.

The occurrence rate of paraparesis was significantly lower in patients with RAxA perfusion; however, there were no significant differences in mortality and occurrence of stroke between patients with and without RAxA cannulation. We cannot demonstrate significant efficacy of RAxA cannulation for the prevention of postoperative stroke and hospital death in patients with dissection and atherosclerosis in the ascending aorta, but the results conversely showed that equivalent excellent outcomes were obtained in patients with aortic dissection and shaggy aorta by using RAxA perfusion.

A BCA clamp was required to establish SACP, and direct clamp and guidewire manipulation for direct arterial cannulation can be primary causes of embolism in patients with atherosclerosis of the aortic arch. Atherosclerosis of the ascending and arch and ruptured aorta were detected as significant risk factors of death in this study, and crucial effects of an atherothrombotic aorta on short-term and long-term outcomes have been reported in total aortic arch repair.[18] The unexpected rapid flow jet of RAxA perfusion was thought to be a risk for embolism of the LCCA in patients with atherosclerosis in the aorta.[19] Considering these factors, a more modified technique of RAxA perfusion will be required for completely eradicating thromboembolism in patients with an atherothrombotic aorta.

On one hand, AxA perfusion through a side graft did not require guidewire manipulation, and significantly lower cannulation-related morbidity rate and stroke occurrence were reported in patients with use of a side graft compared with direct cannulation.[20,21] On the other hand, pitfalls and complications associated with RAxA cannulation have been reported, including new dissection,

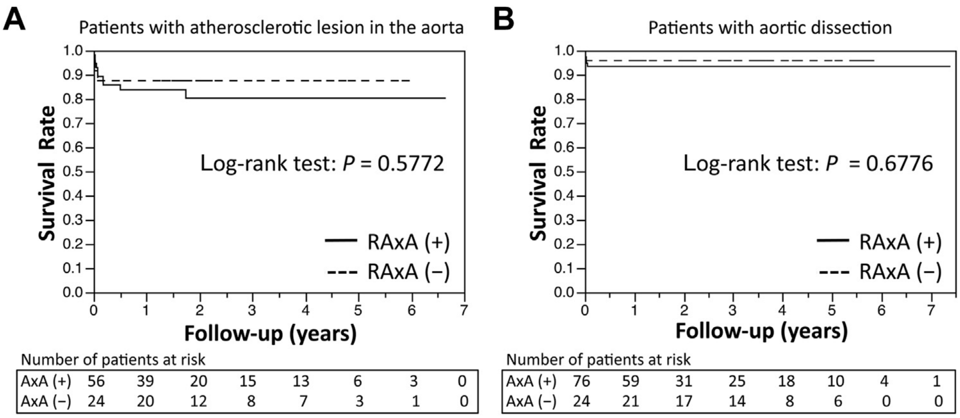

Fig 3. Kaplan-Meier survival on the basis of right axillary artery (*RAxA*) perfusion. **A,** Comparison between patients with and without RAxA perfusion in patients with atherosclerotic disease of ascending aorta and aortic arch. **B,** Comparison between patients with and without RAxA perfusion in patients with aortic dissection.

Table V. Comparison of operative and postoperative data between AxA perfusion with a graft and direct cannulation

Variable[a]	*Graft (n = 29)*	*Direct (n = 113)*	P
Operative time, minutes	487 ± 90	458 ± 119	.045
CPB time, minutes	234 ± 46	229 ± 65	.940
Cardiac arrest time, minutes	139 ± 31	150 ± 40	.231
Cerebral perfusion time, minutes	139 ± 27	134 ± 33	.508
Lower body circulatory arrest time, minutes	64 ± 20	61 ± 19	.118
30-day death	2 (6.9)	6 (5.3)	.666
Hospital death	3 (10.3)	9 (8.0)	.710
Stroke	4 (13.8)	6 (5.3)	.121
Paraparesis	0 (0)	2 (1.8)	1.000
Reexploration for bleeding	2 (6.9)	2 (1.8)	.185
Reintubation	2 (6.9)	7 (6.2)	1.000
Initial ventilation time, hours	78 ± 174	35 ± 49	.026
Mediastinitis	0 (0)	1 (0.9)	1.000
ICU stay, days	6.8 ± 2.0	6.4 ± 10.9	.967
Hospital stay, days	28.8 ± 16.1	30.4 ± 25.2	.595

CPB, Cardiopulmonary bypass; *ICU,* intensive care unit.
[a]Continuous data are shown as mean ± standard deviation and categoric data as number (%).

malperfusion, insufficient flow with high resistance, and arterial injury.[22-24] In this study, the differences in early and midterm postoperative courses between direct cannulation and perfusion via graft were not significant. However, cannulation-related trouble occurred in 4.2% of patients with direct RAxA cannulation. These findings indicated that the priority of the RAxA cannulation technique (direct cannulation or perfusion via graft) remains still controversial.

RAxA perfusion is one of the most useful options for open aortic arch repair with SACP, and midterm survival of patients with RAxA perfusion was satisfactory in our study. However, RAxA perfusion did not prevent stroke in patients with atherosclerotic lesions of the aortic arch, and deciding the optimal cannulation site in these patients was still difficult. Careful selection of the cannulation site according to the patient's pathology and modified approaches for the prevention of embolism, such as gentle and cautious guidewire manipulation or flushing out the debris before BCA clamp, are required to improve the efficacy of RAxA perfusion.

Our study has several limitations. First, this was a nonrandomized retrospective observational study. Second, propensity score was used to reduce selection bias, but the matching is limited, and arbitrariness was not fully denied. Finally, the RAxA was used as one of the cannulation sites to establish SACP in all cases, and efficacy of single use of RAxA perfusion was not evaluated; therefore, ascending aorta and femoral artery cannulation may influence the results.

CONCLUSIONS

RAxA perfusion can be a useful option for total aortic arch repair with SACP, and excellent midterm outcomes were obtained. However, an atherothrombotic aorta was detected as a risk factor of midterm death, and RAxA perfusion was not found to completely prevent stroke in patients with atherothrombotic aorta.

AUTHOR CONTRIBUTIONS

Conception and design: AH
Analysis and interpretation: AH
Data collection: AH, KN, HY
Writing the article: AH, GC
Critical revision of the article: GC, TT, TS
Final approval of the article: HY
Statistical analysis: AH
Obtained funding: Not applicable
Overall responsibility: HY

REFERENCES

1. Patel HJ, Nguyen C, Diener AC, Passow MC, Salata D, Deeb GM. Open arch reconstruction in the endovascular era: analysis of 721 patients over 17 years. J Thorac Cardiovasc Surg 2011;141:1417-23.
2. Zierer A, El-Sayed Ahmad A, Papadopoulos N, Moritz A, Diegeler A, Urbanski PP. Selective antegrade cerebral perfusion and mild (28°C-30°C) systemic hypothermic circulatory arrest for aortic arch replacement: results from 1002 patients. J Thorac Cardiovasc Surg 2012;144:1042-9.
3. Okada K, Omura A, Kano H, Sakamoto T, Tanaka A, Inoue T, et al. Recent advancements of total aortic arch replacement. J Thorac Cardiovasc Surg 2012;144:139-45.
4. Thomas M, Li Z, Cook DJ, Greason KL, Sundt TM. Contemporary results of open aortic arch surgery. J Thorac Cardiovasc Surg 2012;144:838-44.
5. Numata S, Ogino H, Sasaki H, Hanafusa Y, Hirata M, Ando M, et al. Total arch replacement using antegrade selective cerebral perfusion with right axillary artery perfusion. Eur J Cardiothorac Surg 2003;23:771-5.
6. Ogino H, Sasaki H, Minatoya K, Matsuda H, Tanaka H, Watanuki H, et al. Evolving arch surgery using integrated antegrade selective cerebral perfusion: impact of axillary artery perfusion. J Thorac Cardiovasc Surg 2008;136:641-8.
7. Panos A, Murith N, Bednarkiewicz M, Khatchatourov G. Axillary cerebral perfusion for arch surgery in acute type A dissection under moderate hypothermia. Eur J Cardiothorac Surg 2006;29:1036-9.
8. Gulbins H, Pritisanac A, Ennker J. Axillary versus femoral cannulation for aortic surgery: enough evidence for a general recommendation? Ann Thorac Surg 2007;83:1219-24.
9. Ahmed A, Husain A, Love TE, Gambassi G, Dell'Italia LJ, Francis GS, et al. Heart failure, chronic diuretic use, and increase in mortality and hospitalization: an observational study using propensity score methods. Eur Heart J 2006;27:1431-9.
10. Sabik JF, Lytle BW, Mc Carthy PM, Cosgrove DM. Axillary artery: an alternative site of arterial cannulation for patients with extensive aortic and peripheral vascular disease. J Thorac Cardiovasc Surg 1995;109:885-90.
11. Hedayati N, Sherwood JT, Schomisch SJ, Carino JL, Markowitz AH. Axillary artery cannulation for cardiopulmonary bypass reduces cerebral microemboli. J Thorac Cardiovasc Surg 2004;128:386-90.
12. Strauch JT, Spielvogel D, Lauten A, Lansman SL, McMurtry K, Bodian CA, et al. Axillary artery cannulation: routine use in ascending aorta and aortic arch replacement. Ann Thorac Surg 2004;78:103-8.
13. Fong LS, Bassin L, Mathur MN. Liberal use of axillary artery cannulation for aortic and complex cardiac surgery. Interact Cardiovasc Thorac Surg 2013;16:755-8.
14. Pasic M, Schubel J, Bauer M, Yankah C, Kuppe H, Weng YG, et al. Cannulation of the right axillary artery for surgery of acute type A aortic dissection. Eur J Cardiothorac Surg 2003;24:231-5.
15. Reuthebuch O, Schurr U, Hellermann J, Prêtre R, Künzli A, Lachat M, et al. Advantages of subclavian artery perfusion for repair of acute type A dissection. Eur J Cardiothorac Surg 2004;26:592-8.
16. Moizumi Y, Motoyoshi N, Sakuma K, Yoshida S. Axillary artery cannulation improves operative results for acute type a aortic dissection. Ann Thorac Surg 2005;80:77-83.
17. Etz CD, Plestis KA, Kari FA, Silovitz D, Bodian CA, Spielvogel D, et al. Axillary cannulation significantly improves survival and neurologic outcome after atherosclerotic aneurysm repair of the aortic root and ascending aorta. Ann Thorac Surg 2008;86:441-6.
18. Okada K, Omura A, Kano H, Inoue T, Oka T, Minami H, et al. Effect of atherothrombotic aorta on outcomes of total aortic arch replacement. J Thorac Cardiovasc Surg 2013;145:984-91.
19. Minakawa M, Fukuda I, Inamura T, Yanaoka H, Fukui K, Daitoku K, et al. Hydrodynamic evaluation of axillary artery perfusion for normal and diseased aorta. Gen Thorac Cardiovasc Surg 2008;56:215-21.
20. Sabik JF, Nemeh H, Lytle BW, Blackstone EH, Gillinov AM, Rajeswaran J, et al. Cannulation of the axillary artery with a side graft reduces morbidity. Ann Thorac Surg 2004;77:1315-20.
21. Svensson LG, Blackstone EH, Rajeswaran J, Sabik JF 3rd, Lytle BW, Gonzalez-Stawinski G, et al. Does the arterial cannulation site for circulatory arrest influence stroke risk? Ann Thorac Surg 2004;78:1274-84.
22. Sinclair MC, Singer RL, Manley NJ, Montesano RM. Cannulation of the axillary artery for cardiopulmonary bypass: safeguards and pitfalls. Ann Thorac Surg 2003;75:931-4.
23. Schachner T, Nagiller J, Zimmer A, Laufer G, Bonatti J. Technical problems and complications of axillary artery cannulation. Eur J Cardiothorac Surg 2005;27:634-7.
24. Rokkas CK, Angouras D, Chamogeorgakis T, Anagnostopoulos CE. Acute intraoperative aortic dissection following axillary artery cannulation. Interact Cardiovasc Thorac Surg 2008;7:288-9.

Submitted Feb 13, 2014; accepted Feb 21, 2014.